Magnetic paleofield estimates for chondrules extracted from Bjurbole (L4) meteorite

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Introduction: Paleomagnetic intensity estimates from meteorites contain constrains for solar system evolution. Ordinary chondrites, are undifferentiated conglomerates of primitive material, containing intermixed grains of olivine, pyroxene, feldspar and metallic Fe-Ni compounds. These are the materials most likely matched with the S-type asteroids. Ordinary chondrite (H, L, and LL types) magnetism is due to Fe-Ni compounds, primarily α-kamacite (<7% Ni), γ-taenite (>7% Ni), and γ''-tetrataenite (43-52% Ni). During the meteorite entry into the Earth atmosphere the meteorite interior will warm from temperatures on the order of 70-150K to about 300K in the presence of geomagnetic field. This warming event and any weathering that follows has to be considered when analyzing magnetic record of meteorites.

Paleofield estimate:: The paleofield method based on the REM ratio (NRM/SIRM) developed by Kletetschka et al. (2001) [2] reveals paleofields between 12 μT and 45 μT (REM ~ 0.0015-0.0048) for chondrules.

Acquisition of magnetism during the residence inside the geomagnetic field: : Previous magnetic study of Bjurbole (L4) chondrules [1] described very stable remanence directions even after AF demagnetization with 0.24 T Meteorites dominated by Kamacite have very unstable remanent magnetization characterized by rapid intensity decrease upon low (5mT) alternating magnetic field (AF) demagnetization.and chaotic remanence directions The stable magnetization is most likely ascribed to the presence of Tetrataenite and the unstable magnetization with Kamacite. We examined [3] the magnitude of terrestrial contamination associated with the entry of meteorites from space into the terrestrial environment. Most of our experimental magnetic work was done on individual chondrules from Bjurbole (L4) ordinary chondrite. Bjurbole fell 12 March 1899 at 22:30 hours near Borga, Nyland, Finland. One stone fell through the sea-ice and broke into fragments. The total weight was around 330 kilograms and the largest fragment was 80 kilograms. It is classified as an L4 and is very friable. The friability of Bjurbole allowed easy separation of individual chondrules from a bulk piece of the meteorite. Even though separated chondrules are small (1-50 mg) they still posses significant magnetization measurable with our superconducting rock magnetometer (SRM) which is part of Goddard magnetic facility. Remanent magnetization was removed in very detailed steps by alternating field demagnetization. The resulting moment was the initial state of our low temperature experiments. Chondrules were cooled down to liquid nitrogen temperature (77K) in zero external field (background noise up to 1 nT). Chondrules were than exposed to 40,000 nT laboratory field (LF) while at 77K temperature (LFC in Figure 1) and warmed up to a room temperature at 300K. This process should mimic the entrance of the meteorite into the Earth magnetic and thermal environment.

Results: Some chondrules were influenced by the cryogenic and geomagnetic field environment. The low temperature cooling in zero field (ZFC) had significant effect on this group and the magnetization was noted to either rapidly increase or decrease after AF demagnetization (AF dmg). When exposing these chondrules to the geomagnetic field at 77 K a significant component was gained parallel to the lab field (LF). For example one chondrule had upward magnetization ~parallel to the LF. Upon cooling in zero field this component disappeared and a reversed downward component was noted. Exposing the chondrule to the LF at 77K completely reversed its magnetic moment from a downward direction to an upward direction that stabilized close to the ambient lab field (LF). During warming to room temperature the chondrule gained additional magnetic intensity parallel to the LF. Thus the magnetization of this chondrule is extremely sensitive to low values of ambient magnetic field and acquires significant magnetization as soon as exposed to the geomagnetic field. (40,000nT). Other chondrule is a bit more stable because it was able to hold its magnetic moment in direction opposite to geomagnetic field after AF demagnetization as well as when cooled to 70K and exposing to geomagnetic field at this temperature. However, warming to 300K caused this chondrule to gain major component parallel to geomagnetic field as well.

Importantly other chondrules were relatively unaffected. Low temperature treatment has negligible effect on their magnetic remanence. We choose these stable chondrules for paleofield estimates.

Our previous work identified a method how we can detect thermal/chemical type of remanence and distinguish it from isothermal remanent magnetic contamination at low temperature [4]. According to this method two chondrules in our analysis contain TRM/CRM as one component. Another chondrule indicates continuous decay of paleofield value indicating magnetic contamination of low coercivity component by later fields. However, the detailed demagnetization of bj10 reveals stable paleofield consistent with other chondrules revealing contamination field of ~100 mT.

Conclusions: Magnetic record of the Bjurbole chondrite and by analogy perhaps all meteorites is complicated be the fact that it contains magnetic material capable of acquiring a wide range of magnetic remanence records by warming from space temperature and magnetic conditions to 300K inside the terrestrial environment. However, there is also a significant fraction of chondrule record that contains stable remanent directions that is unlikely to be contaminated by exposure to geomagnetic field and terrestrial temperatures. We show that this record is due to TRM/CRM magnetic acquisition and that the acquisition field was close to terrestrial values (15000-45000 nT).

References: [1] Wasilewski, P. et al. (2000) Meteoritics and Planetary Science, 35, 537-544. [2] Kletetschka G. et al. 2003. Meteoritics & Planetary Science 38: 399-405. [3] Kletetschka et al, 2001, 32nd LPSC #1958. [4] Kletetschka et al, 2005, IAGA abstract (Toulouse)